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DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
(ADVANCED RESEARCH PROJECT AGENCY)

Contract Nonr 1858(32) - NR 098-201
(ARPA Order No. 23-59; 23-60 Amend. 19)

# BURNING RATE CONTROL FACTORS

# IN SOLID PROPELLANTS

Fifth Quarterly Technical Summary Report

For the Period 1 January 1960 to 31 March 1960

Aeronautical Engineering Report No. 446-e

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Prepared by: Kimball P. Hall
Kimball P. Hall
Research Associate

and Kimball P. Hall
for E. Karl Bastross
Research Assistant

Approved by: Kimball P. Hall
for Martin Summerfield
Principal Investigator

27 April 1960

Department of Aeronautical Engineering
PRINCETON UNIVERSITY
Princeton, New Jersey

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# I. INTRODUCTION

During the past quarter most of the effort in this program has been devoted to studies of particle size effects on burning rate. As pointed out in previous reports, rates will be determined for propellants prepared from ammonium perchlorate in narrow size distributions. Methods of oxidizer preparation have been developed and sufficient oxidizer has been prepared for several small batches of propellant. Accuracy of burning rate measurement has been improved by modification of the burning rate apparatus. Measurement of burning rates is presently underway, and results will be reported in detail at the end of the next quarter.

Further modification of the burning rate apparatus is underway to control temperature of the purge gas in the strand burner. This will provide closer temperature control than is presently available and will allow operation at both elevated and reduced temperatures in order to determine temperature sensitivity of burning rates. This development will be reported further in later reports.

# II. EFFECTS OF PARTICLE SIZE ON BURNING RATE

## A. Oxidizer Preparation

Ammonium perchlorate oxidizer is prepared in size ranges which are spaced geometrically from 13 to 420 microns. Each range is of such extent that nominally the ratio of the largest particle diameter to the smallest is $\sqrt{2}$. This system provides size fractions of oxidizer particles which are geometrically similar but varying in average size.

Particles in large sizes are prepared by sieving. A Syntron Model TSS-31 sieve shaker is used with U.S. Standard sieves. Oxidizer received from the manufacturer falls mainly between 74 and 420 microns. Using this as a feed material, five size ranges are obtained.

Particles in sub-sieve ranges are obtained by grinding the coarse material in a Bantam Mikro-Pulverizer and classifying by elutriation. The elutriator is an air-gravity device. (For description, see Reference 1.) Particles are classified in a vertically rising air stream, the velocity of the stream determining the cut-point. Superimposed on the steady flow is a periodic pulse of air which serves to agitate the bed of oxidizer being classified. During the past quarter an additional elutriating vessel has been added to the system. There are now two elutriators in series with the air velocity in the first twice that in the second. Oxidizer initially placed in the first is subjected to two cuts and particles are obtained in size ranges with large to small diameter ratios nominally equal to $\sqrt{2}$. An additional modification has been the attachment of metallic-impact vibrators to the elutriator vessels. This type of vibrator has been found to be very effective in preventing particles from adhering to surfaces. With the system in its present form, it is satisfactory for preparing oxidizer for small batches of propellant. The lower the cut-point, the longer the time required for classification. The minimum cut-point for practical purposes is approximately 14 microns. Oxidizer has been prepared in nominal ranges of 14 to 20 microns, and 20 to 28 microns. The size distributions of these two fractions are shown in Figure 1, together with the distributions of the five coarse fractions previously mentioned.* These particles size analyses were obtained by liquid sedimentation as described in Reference 2. Also included in Figure 1 is the distribution of the fine material removed in making the 14 micron cut. This material will also be used in preparing propellant.

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* The distributions of the elutriated factions are not as narrow as those obtained by sieving, but it is expected that they are sufficiently narrow for the purposes of the program.

It has been discovered that as fine particles are removed, the courser material becomes free flowing and moisture sensitivity is reduced. All elutriated oxidizer thus far has been classified from the same initial batch of ground material. One size range has been removed at a time, beginning with the finest. When 28 micron particles and below had been removed, it was found that the remaining material could be sieved. Thus, the sieving range has been extended down to 37 microns (the lowest standard sieve size) by using feed material which has been ground and subsequently elutriated to remove the fines. Three additional size fractions are being prepared by this technique, which are expected to have median diameters, respectively, of about 33, 45, and 64 microns.

B. Propellant Preparation

In selecting a propellant formula for this program, both physical properties and combustion chemistry were considered. In making propellant with oxidizer in narrow size distributions, the oxidizer content must be kept comparatively low, otherwise the viscosity of the uncured propellant becomes too high. Consequently, a fuel is needed which will have a near stoichiometric equivalence ratio at low oxidizer loading. For these reasons, Thiokol LP-3 was selected as a fuel. Maximum oxidizer loading was found to be 65 percent. At greater loading, difficulties are encountered in deaeration and casting. At this loading, the equivalence rat[illegible] 2.0, assuming all sulfur remaining as sulfur in the products. Other work has indicated that this is a valid assumption in this range. This equivalence ratio is equivalent to an oxidizer loading of 75 to 80 percent in other commonly used fuels. Consequently, this appeared to be a good choice of fuel to obtain results which would be of interest. For the first stage of the program all propellant will be prepared from LP-3 with GMF and sulfur as curing agents, and 65 percent by weight of ammonium perchlorate.

Propellant is mixed in 300 to 400 gram batches in an Atlantic Research Corporation Model 35 mixer. Propellant is vacuum cast through a slit deaerator into an evacuated desiccator. The mold, located in the deaerator, is vibrated by means of a small electro-magnetic vibrator to cause the propellant to settle. In order to prevent settling of large oxidizer particles during curing, the mold is sealed on all sides and rotated slowly by an ordinary rotisserie motor while in the oven.

After curing, the rectangular propellant block is cut into 1/4 inch square strands for burning rate measurements. No restrictor material is applied. We have found that in our new style strand burner (in which nitrogen sweeps upward around the strand), polysulfide strands need only be dipped in water briefly (to leach out surface oxidizer) to completely eliminate flashing down the side.

C. Burning Rate Measurement

While our new style of strand burner is basically a Crawford bomb (fuse wires, spaced at intervals of one to five inches, actuate electric clocks as the flame passes by), a modification has been added which is found to considerably increase the accuracy of the measurements. Within the bomb a chimney has been mounted with an internal diameter of approximately one inch. The strand is mounted axially in this chimney and a stream of purge gas (generally nitrogen) flows upwards past the strand during burning. This configuration is shown in Figure 2. The upward flow of gas apparently prevents burning on the sides of the strand and maintains a flat burning surface. The shape of the burning surface has been checked by a water quench system which is associated with the apparatus. Strand burning rates appear to be independent of purge gas velocity except at very low velocities. Rates obtained with this equipment generally show an experimental scatter of less than plus-or-minus 2 percent. This has reduced the number of strands required to determine a burning rate-pressure curve, and, consequently, has reduced the amount of propellant required.

D. Future Particle Size Work

A series of propellants, each containing one of the oxidizer size fractions described in this report, has been prepared. Burning rate measurements on these propellants are in progress. Subsequently burning rates will be run on propellants containing bimodal blends of these fractions and on some containing oxidizer having a broad size distribution. Work beyond this will depend upon the outcome of the present program, but it is probable that variations of fuel concentration and type will receive attention.

## REFERENCES

1. Burning Rate Control Factors in Solid Propellants, Initial Progress Report, Aeronautical Engineering Report No. 446a, Princeton University.

2. Burning Rate Control Factors in Solid Propellants, Fourth Quarterly Status Report, Aeronautical Engineering Report No. 446d, Princeton University.

## FIGURES

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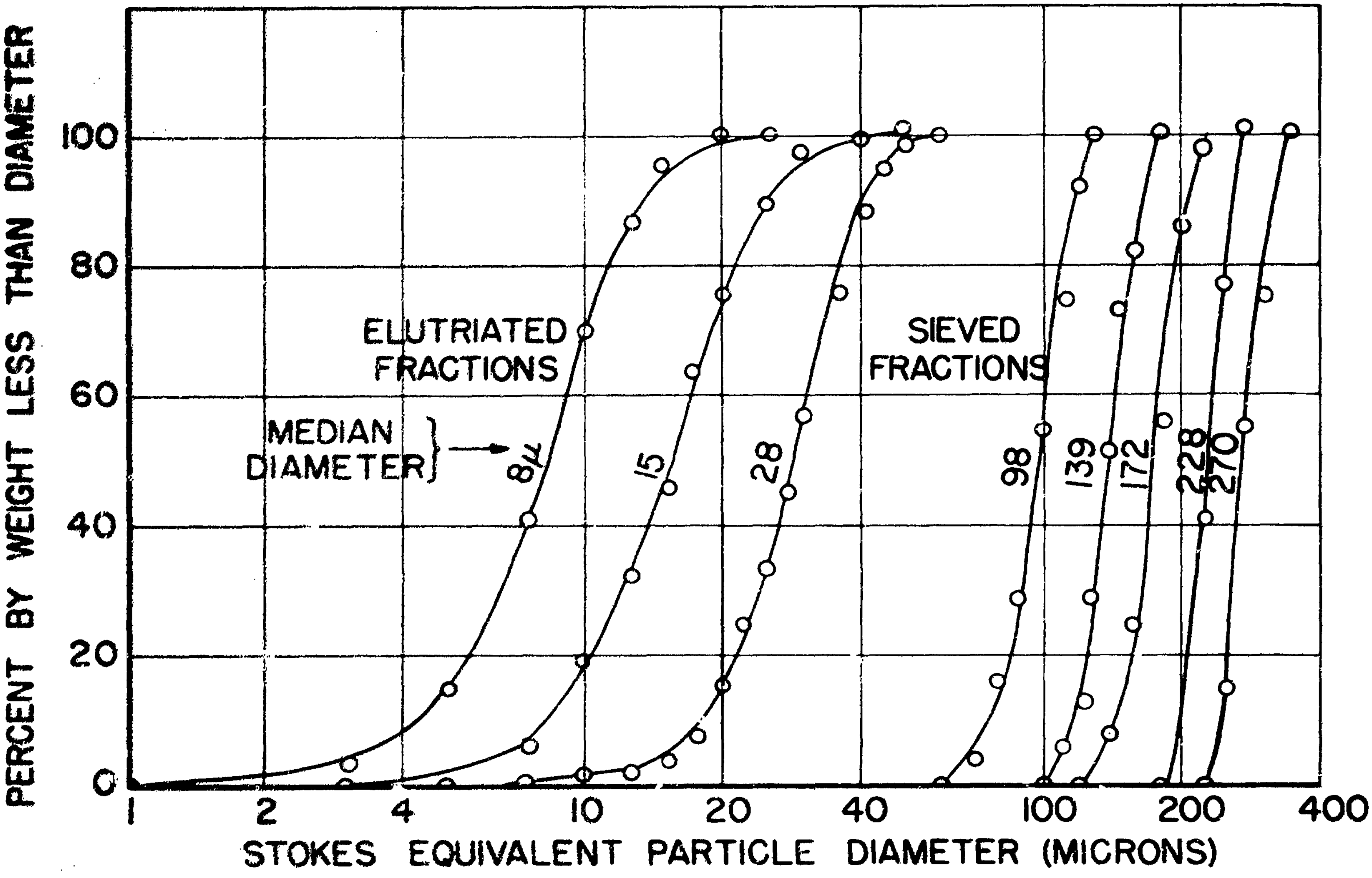
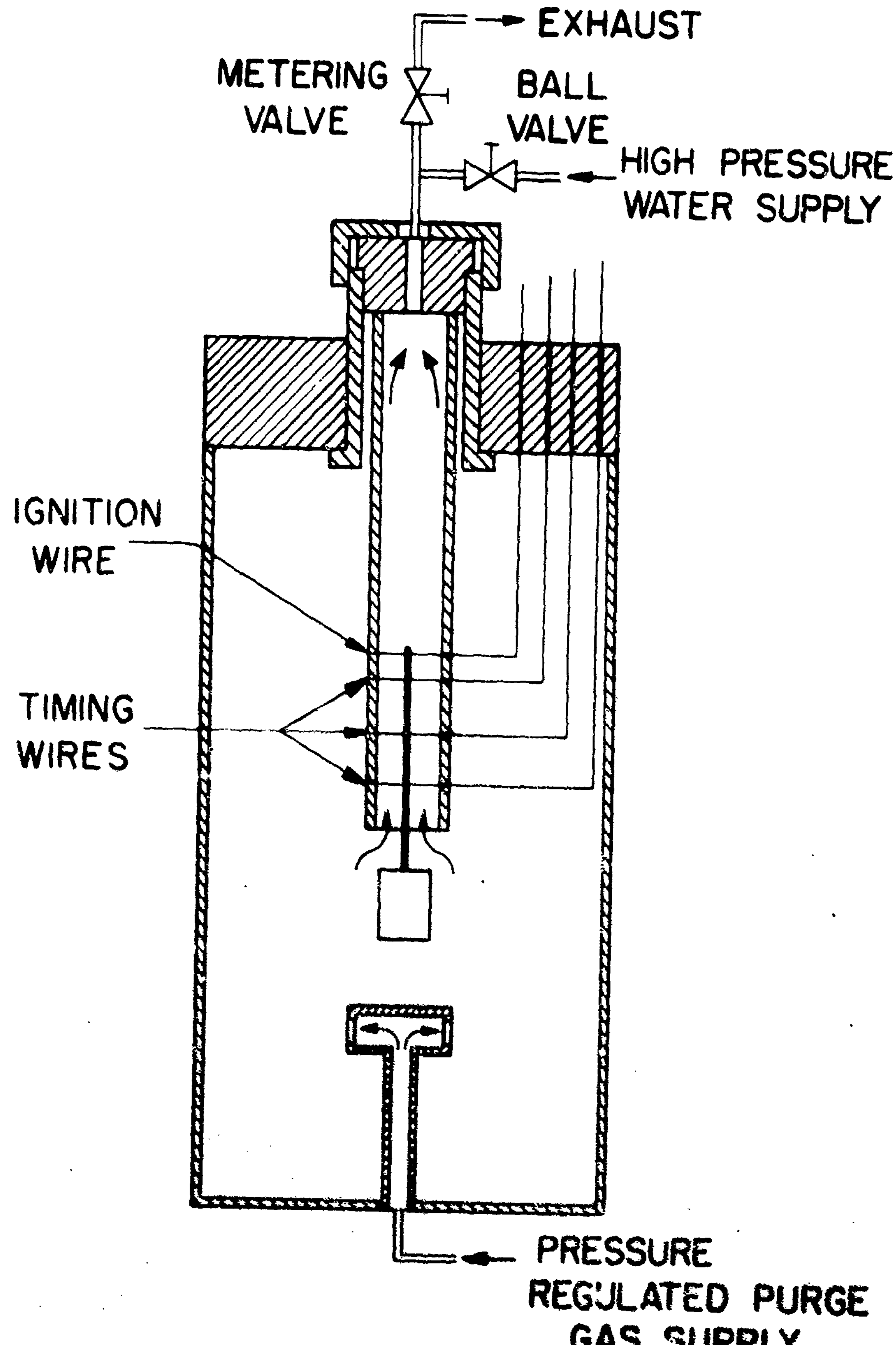



AMMONIUM PERCHLORATE PARTICLE SIZE FRACTIONS

FIGURE I




CHIMNEY STRAND BURNER

FIGURE 2

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